INVESTIGATION 13-A

Half-Life of a Radioactive Isotope

TARGET SKILLS
- Performing and recording
- Analyzing and interpreting
- Communicating results

In the second Multi-Lab at the start of this chapter (Half-Life), you investigated the concept of half-life by flipping coins. This investigation will allow you to actually determine the half-life of a radioactive isotope. A common type of generator for a half-life investigation contains cesium-137, which slowly decays into an excited nucleus, barium-137m. This in turn emits gamma radiation as it drops to its ground state, barium-137. The excited nucleus is leached from the system to provide a slightly radioactive solution.

Problem

The object of this investigation is to determine the half-life of barium-137m.

Equipment

- barium-137m
- Geiger counter
- small test tube and holder
- gloves
- tongs

CAUTION This investigation should be performed as a class demonstration. The experimenter should wear gloves and wash up at the end of the demonstration. All radioactive materials must be safely secured and locked up at the end of the demonstration.

Dispose of the barium solution according to WHMIS procedures.

Procedure

1. Prepare a table with the following headings: Time (min), Measured activity (Bq), Background radiation (Bq), and Net activity (Bq). **Note:** 1 Bq is one count per second.
2. Turn on the Geiger counter and place the tube of the counter close to the test tube holder. Measure an average value for the background radiation.
3. Prepare the barium solution and pour it into the test tube.
4. Take activity readings every half minute until the activity of the source is close to zero.
5. Subtract the background radiation from each reading in order to obtain the activity from the source.

Analyze and Conclude

1. Draw a graph of actual activity against time with the activity on the *y*-axis.
2. From the graph, determine the time interval during which the actual activity decreases by 50%. Repeat this determination in several regions of the graph. How constant is this time interval?
3. What is the half-life of this radioisotope?

Apply and Extend

4. From your graph, how would you determine the rate at which the activity is changing? Perform this determination at two different locations along the curve.
5. Brainstorm a number of possible uses for knowledge of the half-life of a radioisotope.

Applications of Radioactive Isotopes

Exposure to radiation can cause cancer, but it also can destroy cancerous tumours. How can radiation do both?

As you have learned, alpha, beta, and gamma radiation ionize atoms and molecules in their paths. In living cells, the resulting ions cause chemical reactions that can damage critical biological molecules. If that damage occurs in a few very precise regions of the genetic material, the result can be a mutation that destroys the cell's ability to control growth and cell division. Then, the cell divides over and over, out of control, and becomes a cancerous tumour.

On the other hand, if the amount of radiation is much higher, the damage to the molecules that maintain the cell functions will be too great, and the cell will die. If a few healthy cells die, they can usually be replaced, so little or no harm is caused to the individual. If cancerous cells die, the tumour could be destroyed and the person would be free of the cancer.

Great care must be taken when treating tumours with radiation, since healthy cells in the area are exposed to radiation and might themselves become cancerous. If the amount of irradiation is excessive (in a nuclear accident, for example) and the entire body is exposed, too many cells could die at the same time, seriously affecting the ability of the organs to function. Death would result.

Irradiating tumours with gamma radiation is sometimes the only feasible way to treat a tumour, however, and it can be very successful. Figure 13.17 shows one method of treating a tumour with radiation from the radioisotope cobalt-60. A thin beam of gamma rays is aimed at the tumour and then the unit rotates so that the beam is constantly aimed at the tumour. In this way the tumour is highly irradiated, while the surrounding tissue receives much less radiation.

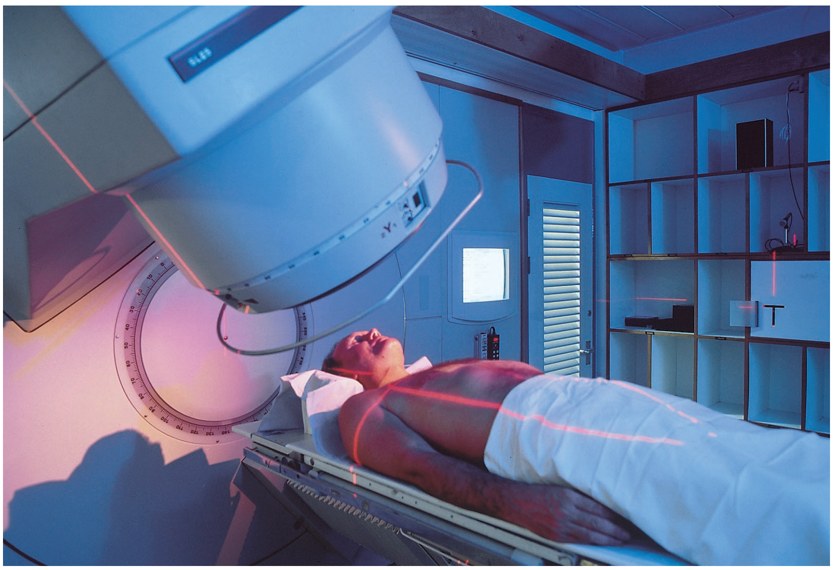

Figure 13.17 Gamma radiation from cobalt-60 is used to destroy tumours.

COURSE CHALLENGE

"Seeing" with Radioisotopes

Techniques exist by which radioisotopes, injected into living bodies, will accumulate in infected areas or other diseased tissues. Observing the location of the radioisotopes provides critical information. Refer to page 605 for ideas to help you include these scanning techniques in your *Course Challenge*.

Radioactive Tracers

Because traces of radioactivity can be detected and identified, scientists can use very small quantities of radioactive substances to follow the chemical or physical activity of specific compounds. For example, iodine-131 is useful for investigating the heart and the thyroid gland. Phosphorus-32 accumulates in cancerous tumours, identifying their location. Technetium-99 portrays the structure of organs. Other applications include the following.

- Slight amounts of a radioisotope added to a fluid passing through an underground pipe allows technicians to locate leaks.
- Gamma radiation is used to sterilize food so that it will stay fresh longer.
- Exposing plants to radioactive carbon dioxide allows researchers to determine the long series of chemical reactions that convert carbon dioxide and water into glucose.
- Radioisotopes are a common tool in biochemistry research.

Smoke Detectors

Many smoke detectors contain a small amount of a radioisotope that emits alpha radiation. Because the gas in the detector is ionized, a current can pass through and be measured. When soot and ash particles in smoke enter the detector, they tend to collect these ions and neutralize them. The resulting drop in current triggers the smoke detector alarm.

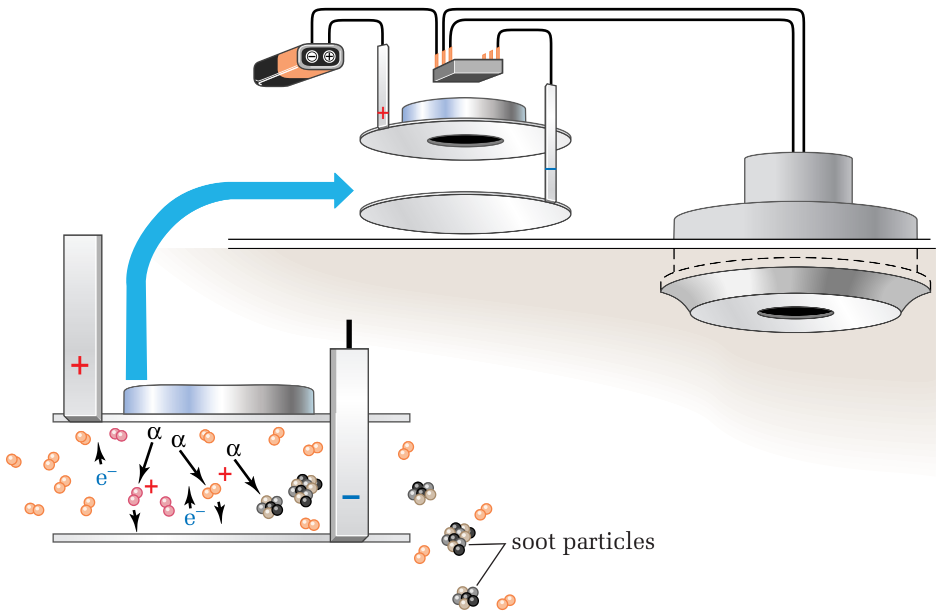

Figure 13.18 When alpha particles ionize molecules in the air, the positive ions are attracted to the negative electrode and the electrons are attracted to the positive electrode and a current passes through the circuit. Soot particles absorb and neutralizes some of the ions and the current decreases.

13.2 Section Review

1. K/U Explain why beta negative radiation tends to do less biological damage than an equal amount of alpha radiation.

2. K/U Which type of particle would you expect to penetrate best through lead, a beta positive particle (positron) or a beta negative particle? Give a reason for your choice.

3. K/U Why is gamma radiation much more penetrating than beta negative radiation?

4. K/U State the conservation laws used in writing nuclear reactions.

5. C Prepare a table for alpha radiation, beta negative radiation, and gamma radiation, comparing them with respect to mass, charge, relative penetrating ability, and relative biological damage.

6. C Draw a graph to illustrate the decay of carbon-14 in a wooden relic. Assume that the initial mass of the isotope in the wood was 240 mg.

7. C Draw a decay sequence similar to the one shown in Figure 13.8 on page 561. Begin with $\left({}^{255}_{101}\mathrm{Md}\right)$. It emits four alpha particles in succession, then a beta negative particle, followed by two alpha particles and then a beta negative particle. Another alpha emission is followed by another beta emission. (There are more, but this is enough for this question.)

8. C Fission is a process in which a nucleus splits into two parts that are roughly half the size of the original nucleus. In fusion, two nuclei fuse, or combine, to form one nucleus. These reactions seem to be opposite to each other, yet they both release large amounts of energy. Explain why this is not really a contradiction. Use the graph of binding energy per nucleon versus atomic mass number in your explanation.

9. MC Give a possible reason why a smoke detector uses an alpha source rather than a beta or gamma emitter.

10. MC Suggest an equation to represent the transformation of nitrogen-14 into carbon-14.

11. I Research the use of radioisotopes for medical or non-medical purposes and prepare a poster to illustrate your findings.

UNIT PROJECT PREP

The eventual identification of radioactivity began as a "mysterious" laboratory result at the turn of the nineteenth century.

- While working on your unit project, have you found information about people who could be called "visionaries" because of their belief that radioactivity would eventually play a role in everyone's daily life?
- Can you identify emerging scientific discoveries that you believe will result in wide-ranging applications by the end of the twenty-first century, as radioactivity has over the past 100 years?